

WORKING GROUP 5: MEASUREMENTS TECHNOLOGY AND ACTIVE EXPERIMENTS

E. Whipple (Chair), J. N. Barfield, C.-G. Fälthammar, J. Feynman
J. N. Quinn, W. Roberts, N. Stone, W. L. Taylor

TECHNOLOGY ISSUES IDENTIFIED BY WORKING GROUP 5:

- (1) New instruments are needed to upgrade our ability to measure plasma properties in space.
- (2) Facilities should be developed for conducting a broad range of plasma experiments in space.
- (3) Our ability to predict plasma weather within magnetospheres should be improved and a capability to modify plasma weather developed.
- (4) Methods of control of plasma spacecraft and spacecraft plasma interference should be upgraded.
- (5) The Space Station laboratory facilities should be designed with attention to problems of flexibility to allow for future growth.

I. MEASUREMENTS OF SPACE PLASMAS

The successful operation of future space systems will require a detailed knowledge of interactions with the plasma environment and the ability to predict its dynamic variations (plasma weather). This will require advances in the measurement of local and remote plasma properties as well as an understanding of the basic physical processes.

In order to achieve these goals, several areas of plasma-measurement technology will need to be advanced to study regions in which measurements have not been previously made and to enhance the capability to measure certain critical items.

One area requiring development is the measurement of plasma properties at low-altitudes (~ 100 km) where the absence of platforms has limited previous data. Several issues need to be resolved regarding the ability to measure low-altitude properties without unduly disturbing the medium.

Another area requiring development is the remote-sensing capability of spaceborne transmitters, for instance as applied to plasmaspheric sounding from the region of geosynchronous orbit. Several areas of measurement will need to be improved in order to develop models of the sources, transport, energization, and loss processes involved in the transport of plasmas throughout the magnetosphere.

A particularly important parameter for which new measurement technology is needed is electric current.

Electric currents in space play a crucial role for plasma processes and for the whole dynamics of the magnetosphere, hence also for the plasma environment of spacecraft and the variations of this environment ("Space Weather"). However, except for low-to medium-altitude Birkeland

currents, which can reasonably well be inferred from magnetometer measurements, very little is known about the currents in the magnetosphere or how they are driven. The reason is that present technology offers no way of directly measuring currents.

An experimental technique for directly measuring electric currents is very much needed.

A strong effort to develop such a technique should be undertaken. A possibility that has been suggested is a technique using the Faraday rotation in optical fibres. This possibility should be investigated in depth.

II. CAPABILITY TO CONDUCT A BROAD RANGE OF PLASMA EXPERIMENTS IN SPACE

The Plasma Processes Laboratory is being defined as a Space Station facility capable of supporting a very broad range of advanced plasma-physics experiments. These experiments range from the creation of and experimentation on dusty plasmas in a microgravity environment, to the creation and study of artificially generated magnetospheres and formation and maintenance of large plasma toroids.

To perform these classes of advanced experiments, a number of enabling technologies need to be addressed and pursued over the next 10 to 15 years.

A. Power and Thermal Control Systems

Many of the classes of experiments being considered will require large amounts of energy to create the necessary energetic system. Thus, studies must be undertaken to provide power (and associated cooling) in the megawatt regime.

B. Lightweight Materials and Support Structures

Since many of the energetic plasma experiments will be contained by magnetic fields, a technology is needed to develop light weight materials and support systems to create and maintain these fields.

C. Techniques for the Development of Gas and Dust Sources and Microgravity Control

Experiments will be performed on dusty plasmas and suspended gases and fluids so controllable sources will be needed. Also since these classes of experiments will be adversely impacted by gravitational acceleration, techniques to maintain a microgravity environment will be required.

D. Commercial Electronic Interfaces

Costs to experimenters can be minimized if commercial electronic interfaces are used rather than the custom interfaces usually used on spacecraft. As an example, many of the plasma-physics experiments will be extensions of laboratory plasma physics on earth, so that the effective transitioning of these experiments requires that the commercial equipment used in earth-based labs be usable on Space Station. This will require the use of commercial interfaces.

III. PREDICTION AND MODIFICATION OF PLASMA WEATHER

The group identified the ability to predict and modify the plasma weather within magnetospheres as a future technology requiring new measurement technologies and the performance of active experiments.

There are several important gaps in the development of this technology; we do not now possess a reliable magnetospheric prediction capability and we are not yet able to induce magnetospheric events.

To upgrade the reliability of prediction, the geo-effective solar terrestrial input to the magnetosphere must be predicted and the response of the magnetosphere to that input modeled. This will allow us to describe the natural environment and to make decisions as to what parameters are to be modified and how that can be accomplished.

Several problems in measurement technology that must be faced in order to produce the required environmental description arose during our discussion and were described in Sections I and II.

Numerical models of the magnetosphere need also to be produced. It has been already demonstrated that important advances in modeling can be made in the next 5 to 10 years using currently available computer technology but it was felt that the physical system was so complex that by 2001 new computer technology would be required. In addition, the ability to handle large coordinated data sets must be further developed. It was expected that both of these requirements would be met without magnetospheric modification acting as a driver for the technology.

To induce magnetospheric events, a technology is required to change the density, energy distribution, composition, and/or flow velocities of the plasma as well as to induce instabilities in the magnetosphere (i.e. control or modify the timing of substorm onsets). The following technologies need further development to facilitate modification of the magnetosphere.

- (1) Injection of high levels of wave power (for example by using very long antennas and developing techniques to deploy them in directions other than the zenith and the nadir) and producing power in a variety of new wavelengths.
- (2) Further development of positive-ion sources.
- (3) Development of an Alfvén maser (a proposed method for dumping electrons and protons from the radiation belts by producing a masing effect in a magnetospheric flux tube. See Burke et al., this conference, and references therein.)

IV. AVOIDANCE OF PLASMA INTERFERENCE ON SPACECRAFT SYSTEMS AND SPACECRAFT-SYSTEMS INTERFERENCE ON PLASMA EXPERIMENTS

The presence of the environmental plasma can cause interference with spacecraft systems and operations (e.g., charging, electrostatic discharges (ESD), energetic particle penetration and memory upsets, and optical surface degradation). Conversely, such phenomena as spacecraft electromagnetic noise, gaseous efflux, and particulate emission can interfere with plasma measurements and plasma experiments.

Present technology needs to be improved and new technology developed to deal with these problems.

Gaps in our present knowledge include:

- (1) How and where electrostatic discharges occur.
- (2) How to actively control charging at the spacecraft.
- (3) How to reduce spacecraft-generated EM noise to a level at which it does not interfere with plasma experiments.
- (4) How to reduce gaseous and particulate emission from manned spacecraft to a level that will not affect plasma experiments.

We need:

- (1) A research program to investigate plasma effects on spacecraft, including experimental studies, additional analyses of existing in situ data and the development of a theoretical model.
- (2) Development of a technology for the active control of charging on a spacecraft.
- (3) Development of an improved method for reducing and/or shielding spacecraft-generated EM noise.
- (4) Development of a technology for reducing and controlling the emission of gasses and particulates from manned spacecraft.

V. DESIGN AND DEVELOP SPACE STATION SYSTEMS FOR GROWTH

Space systems that are expected to grow, such as the Manned Space Station, must be designed and built to accommodate growth. To carry out plasma processes experiments, very high power levels will be required and provision for these technological advances must be made in initial operating capability designs.

NASA, being a project-oriented agency, typically plans projects for fixed costs. However, for systems such as the Manned Space Station that are intended to grow, the initial operating capability must be flexible enough to allow for future requirements. For example, initially the Manned Space Station will have a 25-kW power capability. In future missions powers above the megawatt range are needed and planned. This means that the initial design must include a power distribution system capable of distributing megawatts of power. The alternative, to add wiring and power distribution equipment in parallel with the initial equipment and wiring, would be more expensive in the long run.

The statements of work for the Manned Space Station developers must include provision for growth and evolution of all systems even though in some cases the initial costs will be higher than if the need for growth and evolution were neglected.